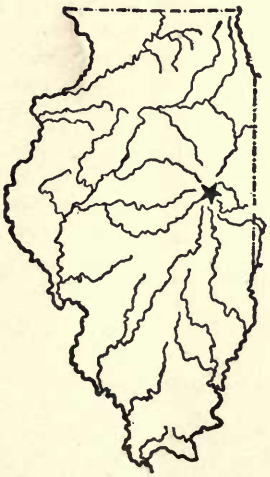
UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 171

A STUDY OF THE PHOSPHORUS CONTENT OF GROWING PIGS

WITH SPECIAL REFERENCE TO THE INFLUENCE OF THE QUANTITY OF PROTEIN CONSUMED

By R. H. WILLIAMS and A. D. EMMETT



URBANA, ILLINOIS, JUNE, 1914

Contents of Bulletin No. 171

A STUDY OF THE PHOSPHORUS CONTENT OF GROWING PIGS

WITH SPECIAL REFERENCE TO THE INFLUENCE OF THE QUANTITY OF PROTEIN CONSUMED[a]

By R. H. WILLIAMS, Fellow in Animal Husbandry, And A. D. EMMETT, Assistant Chief in Animal Nutrition

INTRODUCTION

Phosphorus is one of the most important elements in nutrition, and is therefore closely related to the body functions. It has been shown that, in the case of dairy cows, if the amount of phosphorus consumed falls below a certain minimum, even in a balanced ration, the yield of milk is reduced; in the case of pigs and rabbits, the composition and nature of the bones is modified; in the case of steers, the brittleness of the bones is increased; and in the case of dogs, lambs, calves, pigs, and dairy cows, the general physiological condition is affected adversely.[2] It has been found, also, that phosphorus bears a marked relation to the metabolism of protein and fat.[3]

Phosphorus occurs in the tissues and body fluids in both the inorganic and the organic forms. It is present in all vegetable and animal cells as lecithins, nucleic acids, and nucleo-proteins. Combined with calcium, phosphorus forms one of the chief constituents of the skeleton, and as salts of sodium, potassium, magnesium, and calcium, it constitutes a large proportion of the ash of the muscular and glandular tissues and of the body fluids.

In regard to the value of inorganic phosphates in nutrition[4] there is a difference of opinion. Some investigators believe that these salts are less readily assimilated than the organic phosphorus compounds, and that the calcium salts of phosphorus are available only to a slight extent if at all. Others have shown that the inorganic salts of phosphorus, including the calcium compounds, produce apparently as good results as the organic phosphorus compounds.

---

[a]The results presented in this bulletin, together with those presented in Bulletin 169 of this station,[1] formed part of a thesis submitted by R. H. Williams to the Graduate School of the University of Illinois in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Husbandry.

[1]This and similar reference numbers refer to the bibliography on 226 and 227.

The ultimate object of the investigation of which this publication is a partial report was to determine the influence of different quantities of protein upon the nutrition of *young growing* pigs.[2] This particular bulletin gives the experimental data relating to the phosphorus content of the animal body, and is divided into three parts. The first part deals with the influence of the quantity of protein consumed upon the phosphorus content of the pigs; the second, with the average phosphorus content of pigs 40 to 43 weeks of age; and the third, with the changes in the phosphorus content of pigs that occur during growth.

THE EXPERIMENT

The plan of the experiment is given in detail in Bulletin 168 of this station.[5] In Bulletin 169 of this station,[1] it is described briefly as follows:—

"Of fourteen carefully selected Berkshire pigs weighing on an average 51 pounds, two were slaughtered and analyzed at the beginning of the experiment for a control. The remaining twelve were divided into three lots of four each in such a way that all of the lots were as nearly alike as possible in regard to age, ancestry, weight, and condition. Lot I was fed a low-protein ration, Lot II, a medium-protein ration, and Lot III, a high-protein ration. Each ration consisted of ground corn, blood meal, and calcium phosphate. In the low-protein ration, one-half of the protein was derived from the ground corn, and one-half from the blood meal; in the medium-protein ration, 20 percent of the protein was furnished by the corn, and 80 percent by the blood meal; and in the high-protein ration, 14 percent of the protein came from the corn, and 86 percent from the blood meal. All of the pigs received the same amount of ground corn per 100 pounds live weight. The calcium phosphate[a] was so fed that the rations of Lots I, II, and III contained, respectively, 11.03, 9.65, and 8.73 grams of phosphorus per 100 pounds live weight. In addition, each pig was offered, once a week, about 35 grams of charcoal and 5 grams of salt. They did not seem to show any special desire for either, however, and often left a considerable portion.

"The animals had free access to water and were allowed the freedom of their paved pens. As they grew older and fatter, they were given additional exercise.

"The average amounts of feeds, nutrients, and energy consumed per 100 pounds live weight are given in Table 1.

"*Effect of Rations.*—The experiment lasted 174 days. During this time the differences in the general physical condition and appearance of the pigs became very noticeable. Briefly, the findings were as follows: The pigs of Lot I, the low-protein group, developed slowly, remained small, and appeared to be unthrifty and undernourished. As the experiment progressed, they became sluggish,

[a] According to the results of Hart, McCollum, and Fuller (Wis. Agr. Exp. Sta. Res. Bul. 1), calcium phosphates are as efficient in supplementing rations low in phosphorus as are organic phosphorus compounds. These investigators state that young growing pigs should receive per day at least 6 to 10 grams of phosphorus per 100 pounds live weight.

TABLE 1.—FEEDS, NUTRIENTS, AND ENERGY CONSUMED PER DAY PER 100 POUNDS LIVE WEIGHT

Lot	Animal	Feeds			Digestible nutrients						Ash	Phosphorus	Calcium[b]	Metabolizable energy[c]	Nutritive ratio
						Protein (N x 6.25)									
		Ground corn	Blood meal	Total	Dry substance	Ground corn	Blood meal	Total	Carbohydrates	Fat					
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*grams.*	*grams.*	*grams.*	*therms*	
I	1	2.29	0.22	2.51	1.97	0.16	0.16	0.32	1.55	0.061	71.24	11.03	4.07	3.79	1:5.3
	3[a]	2.40	0.13	2.54	1.99	0.13	0.13	0.26	1.62	0.064	.....	.....	.....	3.90	1:6.8
	4[a]	1.58	0.18	1.76	1.38	0.12	0.12	0.24	1.07	0.042	.....	.....	.....	2.65	1:4.9
II	5	2.14	0.78	2.92	2.27	0.14	0.57	0.71	1.45	0.059	65.26	9.65	3.56	4.32	1:2.2
	7	2.11	0.76	2.87	2.23	0.14	0.55	0.69	1.43	0.059	63.42	9.65	3.56	4.24	1:2.3
	8	1.91	0.72	2.64	2.05	0.13	0.52	0.65	1.29	0.053	53.98	7.71	2.72	3.88	1:2.2
Average.....		2.05	0.75	2.81	2.18	0.14	0.54	0.68	1.39	0.057	60.88	9.00	3.28	4.14	1:2.2
III	16	1.92	1.10	3.02	2.34	0.13	0.80	0.93	1.29	0.055	57.45	8.73	3.22	4.41	1:1.5
	13	2.00	1.14	3.14	2.43	0.13	0.83	0.96	1.35	0.057	60.67	8.73	3.22	4.58	1:1.5
	15	1.82	0.92	2.75	2.13	0.11	0.68	0.79	1.23	0.052	55.34	8.16	3.22	4.02	1:1.7
Average.....		1.91	1.05	2.97	2.30	0.12	0.77	0.89	1.29	0.055	57.82	8.54	3.22	4.33	1:1.6

[a] Died before close of experiment.

[b] Calculated from average composition of feeds.

[c] The metabolizable energy of a ration is the energy than can be liberated in the animal body, or the gross energy less the energy contained in the feces, urine, and intestinal gases. The metabolizable energy of the rations has been calculated by multiplying the weights of the digestible nutrients by the following factors: digestible protein, 1860; digestible carbohydrates, 1905; and ether extract, 3992. One therm equals 1000 calories.

and, toward the end walked with difficulty. Pig 2 become so ill that it was removed on the forty-sixth day and given the ration of the Station herd. It died a week later. Two of the three remaining pigs in this lot died before the close of the experiment. The kidneys of these pigs were small and in a pathological condition, showing a chronic state of parenchymatous nephritis. The remaining pig, No. 1, which at the beginning of the experiment was considered to be the most thrifty of the animals selected, made fair gains, averaging 0.64 pound per day. However, the kidneys of this animal were found to be small and in the same pathological condition as those of the other two. The livers were small, but otherwise normal.

"Early in the experiment, when Pig 2 died, one pig was removed from each of Lots II and III in order to make the three lots directly comparable from the standpoint of merit of the animals, number of animals, and area per head in each pen.

"The remaining pigs of the medium- and high-protein lots showed practically none of the unfavorable symptoms apparent in the pigs of Lot I, tho at times during very cold weather they were stiff in the hind quarters. In general, however, these animals were thrifty and active, and had good appetites. Also, considering that they were kept in pens, they made good gains, Lot II averaging 0.96 pound per pig per day, and Lot III, 0.94 pound.

"Since the chief and essential difference between the rations given Lots I, II, and III was in their content of protein, it would seem that a deficiency of protein in the feed was the chief cause of the poor development of the animals of Lot I.

"Attention should again be called to the fact that the pigs used in this investigation were young growing animals weighing on an average only 51 pounds at the beginning of the experiment, and that they were housed in small pens paved with brick. The reader is cautioned against assuming that similar results would have been obtained if they had been more mature.

"*Animals Slaughtered and Analyzed.*—Both of the pigs of Lot IV, Nos. 26 and 44, were slaughtered and analyzed at the beginning of the experiment for a control. These animals were by the same sire and of the same age. At the time that they were slaughtered they weighed 61.0 and 54.7 pounds, respectively. The pigs chosen for slaughter and chemical study at the close of the experiment were Nos. 1 of Lot I, 5 and 7 of Lot II, and 16 and 13 of Lot III. At the time they were slaughtered these animals weighed, respectively, 180.1, 249.4, 199.6, 248.4, and 189.3 pounds. Pigs 1, 5, and 16 were of the same age. They were also related, No. 1 being a litter mate of No. 5, and No. 16 being by the same sire as Nos. 1 and 5. Pigs 7 and 13 were litter mates and twenty days younger than Nos. 1, 5, and 16.

"Seven composite samples were prepared from each pig of Lots I, II, and III. These were: (1) the offal, consisting of the organs of the respiratory, circulatory, and digestive systems, the brain, the spinal cord, the kidneys, and the urinary organs, etc.; (2) the blood; (3) the skeleton; (4) the jowl, leaf, and intestinal fats; (5) the boneless meat of the ham cut; (6) the boneless meat of the side cut; and (7) the boneless meat of the shoulder cut. These samples represented integral parts of the entire body, and from the determinations of their weights and composition the chemical composition of the boneless meat of the dressed carcass and the entire body of each pig was calculated. Only four composite samples were prepared from each pig of Lot IV, i. e., offal, skeleton, composite of the jowl, leaf, and intestinal fats, and boneless meat of the carcass."

Methods of Analysis.—The phosphorus determinations made on each sample were: total phosphorus, water-soluble phosphorus, and soluble inorganic phosphorus. From these three sets of data it was possible to calculate the insoluble phosphorus and also the soluble organic phosphorus. Only the total phosphorus was determined in the composite samples from the control lot, No. IV.

The total and the soluble phosphorus were determined in the residues from the ash. The residues were digested on the steam bath for 4 hours with strong nitric acid, then filtered, and the phosphorus separated by the official gravimetric method. Tests made in this laboratory by Grindley and Petersen in the case of meats showed that none of the phosphorus is volatilized during the ashing, and that the ash is completely dissolved by the acid digestion. The water-soluble inorganic phosphorus was determined by the Emmett and Grindley modification of the method of Hart and Andrews.[6]

INFLUENCE OF QUANTITY OF PROTEIN CONSUMED

The data relating to the forms of phosphorus in the bodies of the pigs and the various parts are given in Tables 2, 3, 6, 7, 8, and 9. Tables 2, 6, and 8 give the results expressed in percent of the fresh substance, and Tables 3, 7, and 9, the results on the basis of the dry and fat-free substance. Thruout this bulletin the term "phosphorus" refers to the element, P, and not to the oxide, P_2O_5. To calculate the data to the oxide by 2.293.

Total Phosphorus.—The values of Pig 1 of Lot I for the total phosphorus in percent of the fresh substance (Table 2) were not, as a rule, distinctly different from those of the pigs of Lots II and III. For some samples its values fell between those of the pigs of the other lots, while for other samples its values were not significantly higher or lower than those of Lots II and III. For example, for the offal, the value of Pig 1 was intermediate between the percentages of Pigs 16 and 13 of Lot III, while for the blood, the value of Pig 1 was the same as that of Pig 5 of Lot II.

Upon comparing the corresponding values for Lots II and III in Table 2, it will be seen that the average percentages of the medium-protein lot were practically the same as those of the high-protein lot. In fact, for most samples the differences between the values for the individual pigs within these lots were as great as, or greater than, the differences between the lots. Thus, in the case of the offal, the difference between the values of Pigs 5 and 7 of Lot II was 0.005 percent, and that between the values of Pigs 16 and 13 of Lot III, 0.006 percent, while the difference between the averages of Lots II and III was only 0.003 percent.

The values of the three lots were very similar also in the case of the total phosphorus expressed in percent of the dry and fat-free substance (Table 3). In these data again, as in the data for the phosphorus expressed in percent of the fresh substance, the differences between the values of the individual animals for some samples were greater than the differences between the averages for the lots.

TABLE 2.—TOTAL PHOSPHORUS IN THE BODY AND ITS PARTS

(Results expressed in percent of fresh substance)

Lot	Animal	Offal[b]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	0.148	0.113	5.69	0.016	0.154	0.132	0.115	0.129	0.728
II	5	0.150	0.113	6.49	0.020	0.153	0.135	0.103	0.122	0.672
II	7	0.155	0.117	5.90	0.034	0.154	0.128	0.109	0.125	0.690
Average . ..	..	0.152	0.115	6.19	0.027	0.153	0.131	0.106	0.123	0.681
III	16	0.146	0.127	6.41	0.028	0.138	0.133	0.099	0.117	0.685
III	13	0.152	0.130	5.64	0.031	0.153	0.128	0.106	0.123	0.673
Average . ..	..	0.149	0.128	6.03	0.029	0.145	0.130	0.102	0.120	0.679
Average (5)	..	0.150	0.120	6.03	0.026	0.150	0.131	0.106	0.123	0.690
IV	26	0.185	(c)	4.36	0.066	(c)	(c)	(c)	0.286	0.631
IV	44	0.185	(c)	3.79	0.088	(c)	(c)	(c)	0.260	0.570
Average . ..	..	0.185	(c)	4.07	0.077	(c)	(c)	(c)	0.273	0.600

TABLE 3.—TOTAL PHOSPHORUS IN THE BODY AND ITS PARTS[a]

(Results expressed in percent of dry and fat-free substance)

Lot	Animal	Offal[b]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	0.676	0.563	10.54	0.591	0.975	1.033	1.045	0.905	3.935
II	5	0.649	0.584	10.85	0.641	0.971	0.979	1.209	0.955	3.889
II	7	0.705	0.616	10.53	0.936	0.978	0.991	1.414	0.955	4.023
Average . ..	..	0.677	0.600	10.69	0.788	0.974	0.985	1.311	0.955	3.956
III	16	0.567	0.605	10.89	0.997	0.953	0.974	1.452	0.871	4.042
III	13	0.663	0.620	10.34	0.955	1.057	0.968	1.133	0.951	3.824
Average . ..	..	0.615	0.612	10.61	0.976	1.005	0.971	1.292	0.911	3.933
Average (5)	..	0.652	0.598	10.63	0.824	0.987	0.989	1.251	0.927	3.943
IV	26	0.953	(c)	9.92	0.961	(c)	(c)	(c)	1.629	3.064
IV	44	0.953	(c)	9.02	1.643	(c)	(c)	(c)	1.624	2.934
Average . ..	..	0.953	(c)	9.47	1.302	(c)	(c)	(c)	1.626	2.999

[a]Calculated from data given in Tables 4 and 5.

[b]Includes blood.

[c]Not analyzed.

TABLE 4.—DRY SUBSTANCE IN THE BODY AND ITS PARTS

(Results expressed in percent of fresh substance)

Lot	Animal	Offal[a]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	35.74	20.05	66.13	91.76	47.47	52.66	63.32	56.69	56.15
II	5	35.49	19.38	67.97	90.55	47.99	51.05	66.09	58.38	57.13
II	7	33.85	18.98	66.89	86.72	46.92	53.98	68.64	59.52	57.43
Average . . .	..	34.67	19.18	67.43	88.63	47.45	52.51	67.36	58.95	57.28
III	16	36.71	20.99	65.32	90.89	49.65	49.80	68.30	59.11	57.78
III	13	35.43	20.95	63.99	87.83	50.20	52.26	66.28	58.81	56.43
Average . . .	..	36.07	20.97	64.65	89.36	49.92	51.03	67.29	58.96	57.10
Average (5)	..	35.44	20.07	66.06	89.55	48.45	51.95	66.53	58.50	56.98
IV	26	35.02	(b)	50.91	84.28	(b)	(b)	(b)	38.36	38.83
IV	44	35.29	(b)	49.22	81.48	(b)	(b)	(b)	43.94	41.82
Average . . .	..	35.15	(b)	50.06	82.88	(b)	(b)	(b)	41.15	40.32

TABLE 5.—FAT IN THE BODY AND ITS PARTS

(Results expressed in percent of fresh substance)

Lot	Animal	Offal[a]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	11.96	(b)	12.15	89.06	30.85	37.96	50.38	42.41	36.90
II	5	10.53	(b)	8.15	87.43	31.96	36.74	55.36	45.60	38.98
II	7	10.16	(b)	10.54	83.09	30.76	40.14	57.42	46.44	38.24
Average . . .	..	10.34	(b)	9.35	85.26	31.36	38.44	56.39	46.02	38.61
III	16	9.60	(b)	6.46	88.08	34.04	34.40	56.89	45.68	38.75
III	13	10.68	(b)	9.44	84.58	34.23	38.06	55.42	45.89	37.93
Average . . .	..	10.14	(b)	7.95	86.33	34.14	36.23	56.15	45.79	38.34
Average (5)	..	10.58	(b)	9.35	86.45	32.37	37.72	55.09	45.20	38.16
IV	26	15.16	(b)	6.96	77.41	(b)	(b)	(b)	20.81	18.24
IV	44	15.89	(b)	7.21	76.12	(b)	(b)	(b)	27.91	22.39
Average . . .	..	15.52	(b)	7.08	76.76	(b)	(b)	(b)	24.36	20.32

[a]Includes blood.

[b]Not analyzed.

Water-Soluble Phosphorus.—The data for the water-soluble phosphorus given in Table 6 show the same general tendency as the data for the total phosphorus. Accordingly, the differences in the rations of the low-, medium-, and high-protein lots did not produce any distinct effect upon the percentages of water-soluble phosphorus in the body and its parts. This is indicated also by the data for the water-soluble phosphorus in percent of the dry and fat-free substance given in Table 7.

TABLE 6.—WATER-SOLUBLE PHOSPHORUS IN THE BODY AND ITS PARTS

(Results expressed in percent of fresh substance)

Lot	Animal	Offal[a]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	0.098	0.113	0.035	0.011	0.114	0.105	0.075	0.085	0.082
II	5	0.108	0.113	0.036	0.013	0.116	0.095	0.069	0.083	0.080
II	7	0.089	0.117	0.032	0.018	0.107	0.094	0.072	0.080	0.078
Average . . .	..	0.098	0.115	0.034	0.015	0.111	0.094	0.070	0.081	0.079
III	16	0.103	0.127	0.030	0.016	0.096	0.099	0.078	0.083	0.080
III	13	0.102	0.130	0.034	0.014	0.108	0.094	0.072	0.083	0.080
Average . . .	..	0.102	0.128	0.032	0.015	0.102	0.096	0.075	0.083	0.080
Average (5)	..	0.100	0.120	0.033	0.014	0.108	0.098	0.073	0.083	0.079

TABLE 7.—WATER-SOLUBLE PHOSPHORUS IN THE BODY AND ITS PARTS

(Results expressed in percent of dry and fat-free substance)

Lot	Animal	Offal[a]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	0.447	0.563	0.065	0.406	0.686	0.714	0.580	0.595	0.426
II	5	0.469	0.584	0.061	0.417	0.724	0.664	0.643	0.642	0.441
II	7	0.405	0.616	0.057	0.495	0.662	0.679	0.642	0.612	0.406
Average . . .	..	0.437	0.600	0.059	0.456	0.693	0.708	0.643	0.618	0.423
III	16	0.404	0.605	0.051	0.569	0.615	0.643	0.684	0.618	0.420
III	13	0.444	0.620	0.062	0.431	0.676	0.662	0.606	0.642	0.432
Average . . .	..	0.424	0.612	0.056	0.500	0.645	0.718	0.645	0.630	0.426
Average (5)	..	0.434	0.598	0.059	0.464	0.673	0.672	0.631	0.622	0.425

[a]Includes blood.

Water-Soluble Inorganic Phosphorus.—As far as the relationship between the averages of the three lots was concerned, the results obtained for the water-soluble inorganic phosphorus given in Tables 8 and 9 corresponded in the case of the offal, blood, skeleton, and composite of the jowl, leaf, and intestinal fats, to the results for the total phosphorus and the total water-soluble phosphorus. In the case of the data for the boneless meat of the ham, shoulder, and side cuts, however, the values for the water-soluble inorganic phosphorus of Lot II were slightly higher than those of Lot III. Whether this fact was significant or not, it is difficult to decide, as the differences between the values of the individual animals for some of the samples varied greatly. Between the values for the boneless meat of the entire carcass in percent of the fresh substance, the difference was slight. On the basis of the dry and fat-free substance, the percentage of water-soluble inorganic phosphorus of the medium-protein lot was higher than that of the high-protein lot.

The values of Lot I for the ham cut in percent of the fresh substance were slightly lower than those of Lot II, and about the same as those of Lot III. In the case of the shoulder cut, they were higher than those of Lot III, and corresponded more closely to those of Lot II. In the case of the side cut, they were higher than the average of both Lots II and III. On the basis of the dry and fat-free substance, the values of Lot I for the same three cuts agreed more closely with those of Lot III.

TABLE 8.—WATER-SOLUBLE INORGANIC PHOSPHORUS IN THE BODY AND ITS PARTS

(Results expressed in percent of fresh substance)

Lot	Animal	Offal[a]	Blood[b]	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	0.077	0.033	0.032	0.007	0.096	0.089	0.077	0.076	0.071
II	5	0.084	0.033	0.029	0.009	0.103	0.095	0.067	0.076	0.072
II	7	0.070	0.033	0.028	0.013	0.108	0.087	0.066	0.074	0.070
Average . . .	..	0.077	0.033	0.028	0.011	0.105	0.091	0.066	0.075	0.071
III	16	0.075	0.033	0.026	0.011	0.095	0.081	0.064	0.071	0.067
III	13	0.084	0.033	0.031	0.011	0.092	0.079	0.062	0.071	0.067
Average . . .	..	0.079	0.033	0.028	0.011	0.093	0.080	0.063	0.071	0.067
Average (5)	..	0.078	0.033	0.029	0.010	0.099	0.086	0.067	0.074	0.069

[a]Includes blood.

[b]Calculated from values given by Abderhalden.

TABLE 9.—WATER-SOLUBLE INORGANIC PHOSPHORUS IN THE BODY AND ITS PARTS

(Results expressed in percent of dry and fat-free substance)

Lot	Animal	Offal[a]	Blood[b]	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
						Ham	Shoulder	Side	Carcass	
I	1	0.351	0.160	0.059	0.259	0.578	0.599	0.587	0.532	0.369
II	5	0.364	0.170	0.049	0.289	0.642	0.664	0.624	0.595	0.397
II	7	0.318	0.174	0.050	0.358	0.668	0.629	0.588	0.566	0.365
Average . . .	..	0.341	0.172	0.049	0.323	0.655	0.646	0.606	0.580	0.381
III	16	0.294	0.157	0.041	0.391	0.609	0.526	0.561	0.529	0.352
III	13	0.366	0.157	0.057	0.338	0.576	0.556	0.521	0.550	0.362
Average . . .	..	0.330	0.157	0.049	0.364	0.592	0.541	0.541	0.539	0.357
Average (5)	..	0.339	0.164	0.051	0.327	0.615	0.595	0.576	0.554	0.369

[a]Includes blood.

[b]Calculated from values given by Abderhalden.

Relation of the Three Forms of Phosphorus.—The relation of the values for the total, the water-soluble, and the water-soluble inorganic phosphorus is shown graphically by Figs. 1, 2, and 3 on pages 228 and 229. The curves for the three lots are closely correlated, and indicate that the influence exerted by the differences in the quantities of protein consumed were extremely slight.

Phosphorus Stored in Body.—The amounts of phosphorus stored in the bodies of the pigs of the three lots from the beginning to the end of the experiment are given in Table 10. The values for the weights of phosphorus in the bodies at the beginning of the experiment were obtained by calculating the average values found for the pigs of Lot V to the basis of the live weight of each of the pigs of Lots I, II, and III when the experiment began.

The data show clearly that the percentage increase in the case of Pig 1 was significantly smaller than the percentages of increase in the case of the pigs of Lots II and III. Between the values of the medium and high-protein lots there was little difference.

Phosphorus Stored in Body in Percent of Phosphorus Consumed.—The phosphorus stored in the bodies of the five pigs of Lots I, II, and III in percent of the phosphorus consumed during the experiment varied directly as the amounts of protein consumed, the smallest percentage being that of Lot I, and the largest, that of Lot III. The difference between the values of Lots II and III was much smaller than that between Lots I and II, or that between Lots I and III.

On comparing these data with the data for the amounts of phosphorus consumed per 100 pounds live weight (Table 1), it will be noted that the percentage of phosphorus stored varied inversely as the amounts of phosphorus consumed. When the percentages stored by the pigs of the low- and high-protein lots were calculated to the basis of the amounts of phosphorus consumed per 100 pounds live weight by the pigs of the medium-protein lot, it was found that the percentages stored by all three lots were practically the same, i. e., 23.81, 23.85, and 23.10 percent, respectively, for Lots I, II, and III. This fact would seem to indicate that the percentages of phosphorus stored were not dependent upon the amounts of protein consumed, but varied inversely as the amounts of phosphorus consumed per 100 pounds live weight.

TABLE 10.—PHOSPHORUS STORED IN THE BODY

Lot	Animal	Weight of phosphorus consumed	Phosphorus stored in the body				Weight of phosphorus metabolized	Relation of phosphorus stored to phosphorus consumed
			Weight at beginning	Weight at end	Weight stored	Percentage increase		
		grams	*grams*	*grams*	*grams*	*percent*	*grams*	*percent*
I	1	2100.12	154.22	544.31	390.09	252.56	1710.03	18.57
II	5	2349.60	145.15	693.99	548.84	378.12	1800.76	23.36
II	7	1900.54	113.40	576.05	462.65	407.97	1437.89	24.34
Average.	..	2125.07	129.27	635.02	505.74	393.04	1619.33	23.85
III	16	2267.95	145.15	716.67	571.52	393.75	1696.43	25.28
III	13	1587.56	104.32	517.09	412.77	395.68	1174.79	26.00
Average.	..	1927.75	124.73	616.88	492.14	394.72	1435.61	25.64

AVERAGE PHOSPHORUS CONTENT OF GROWING PIGS 40 TO 43 WEEKS OLD

It is evident from the data in the preceding section of this bulletin that the differences in the quantities of protein consumed exerted no significant influence upon the quantities or the distribution of the phosphorus in the bodies of the pigs. Accordingly, the average values for the five pigs slaughtered may be regarded as representing approximately the average phosphorus content of pigs 40 to 43 weeks of age.

TABLE 11.—AVERAGE PHOSPHORUS CONTENT OF PIGS OF LOTS I, II, AND III

	Offal[a]	Blood	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat				Entire body
					Ham	Shoulder	Side	Carcass	
Total Phosphorus									
In percent of fresh substance	0.150	0.120	6.03	0.026	0.150	0.131	0.106	0.123	0.690
In percent of dry and fat-free substance	0.652	0.598	10.63	0.824	0.987	0.989	0.251	0.927	3.943
Grams per 100 lbs. live weight	13.26	1.78	262.66	0.78	9.59	10.54	15.44	35.58	312.29
In percent of total phosphorus in entire body	4.25	0.57	84.11	0.25	3.07	3.37	4.94	11.39	100.00
Water-Soluble Phosphorus									
In percent of fresh substance	0.100	0.120	0.033	0.014	0.108	0.098	0.073	0.083	0.079
In percent of dry and fat-free substance	0.434	0.598	0.059	0.464	0.673	0.672	0.631	0.622	0.425
Grams per 100 lbs. live weight	8.97	1.78	1.45	0.44	6.90	7.81	10.71	25.42	36.28
In percent of water-soluble phosphorus in entire body	24.73	4.91	4.00	1.21	19.02	21.52	29.52	70.06	100.00
In percent of total phosphorus in the body and each part	67.67	100.00	5.52	56.21	71.37	74.05	69.35	71.44	11.61
Water-Soluble Inorganic Phosphorus									
In percent of fresh substance	0.078	0.033[b]	0.029	0.010	0.099	0.086	0.067	0.074	0.069
In percent of dry and fat-free substance	0.339	0.164	0.051	0.327	0.615	0.595	0.576	0.554	0.369
Grams per 100 lbs. live weight	6.82	0.49	1.26	0.31	6.29	6.93	9.78	23.04	31.45
In percent of water-soluble inorganic phosphorus in entire body	21.70	1.56	4.01	0.99	20.17	22.03	31.10	73.30	100.00
In percent of total phosphorus in the body and each part	51.45	27.58	4.80	39.87	66.10	65.70	63.32	64.77	10.07
In percent of water-soluble phosphorus in the body and each part	76.02	27.58	86.93	70.93	91.91	88.71	91.30	90.67	86.66

[a]Includes blood.

[b]From value given by Abderhalden.

Total Phosphorus.—On the basis of the fresh substance, the total phosphorus for the five pigs varied from 0.026 percent in the composite of the jowl, leaf, and intestinal fats, to 6.03 per cent in the skeleton (bone and marrow). The percentage in the boneless meat of the cuts was lowest in the side, and highest in the ham, the values for these parts being 0.106 and 0.150 percent, respectively. The average percentage of phosphorus in the entire body was 0.690[a].

On the basis of the dry and fat-free substance, the total phosphorus ranged from 0.598 percent in the blood to 10.63 percent in the skeleton. The boneless meat of the ham cut contained 0.987 percent, and the boneless meat of the side cut, 1.251 percent. The entire body contained 3.943 percent.

The amount of phosphorus in the body per 100 pounds live weight varied from 0.78 gram in the composite of the jowl, leaf, and intestinal fats to 312.29 grams in the entire body. The offal contained 13.26 grams, and the skeleton, 262.66 grams.

The values for the phosphorus in the parts in percent of the total phosphorus in the entire body ranged from 0.25 percent in the composite of the jowl, leaf, and intestinal fats to 84.11 percent in the skeleton. The boneless meat of the carcass contained 11.39 percent[b].

Water-Soluble Phosphorus.—The water-soluble phosphorus in percent of the fresh substance varied from 0.014 percent in the composite of the jowl, leaf, and intestinal fats to 0.120 percent in the blood. The arrangement of the parts according to increasing content was as follows: composite of jowl, leaf, and intestinal fats; skeleton; meat of side cut; meat of shoulder cut; offal; meat of ham cut; and blood. The average percentage in the entire body was 0.079[a].

On the basis of the dry and fat-free substance, the values for the various parts ranged from 0.059 percent in the skeleton to 0.673 percent in the boneless meat of the ham cut. The order of the parts according to increasing value was as follows: skeleton; offal; composite of jowl, leaf, and intestinal fats; blood; meat of side cut; meat of shoulder cut; and meat of ham cut.

As would be expected, the amount of water-soluble phosphorus per 100 pounds live weight was distinctly lower than the amount of total phosphorus for the corresponding parts. The most marked differences were found in the skeleton and the entire body; the former contained 262.66 grams of phosphorus of which only 1.45 grams were soluble in water, and the latter, 312.29 grams of phosphorus of which only 36.28 grams were soluble in water.

---

[a]See Fig. 4, page 229.

[b]See Fig. 5, page 230.

Expressed in percent of the total water-soluble phosphorus in the entire body, the distribution of the water-soluble phosphorus differed decidedly from that of the total phosphorus. Thus, the skeleton contained only 4.00 percent of the total water-soluble phosphorus in the entire body, and 84.11 percent of the total phosphorus; the offal, and the meat of the ham, shoulder, and side cuts contained from 19.02 percent to 29.52 percent of the total water-soluble phosphorus, and from 3.07 to 4.94 percent of the total phosphorus; and the boneless meat of the entire carcass contained 70.06 percent of the total water-soluble phosphorus, and only 11.39 percent of the total phosphorus[a].

On the assumption that all of the phosphorus in the blood is soluble in water, the data given in Table 11 show that the water-soluble phosphorus of the body and the parts expressed in percent of the total phosphorus in the body and each part, varied from 5.52 percent in the skeleton to 100.00 percent in the blood. Of the total phosphorus in the entire body, 11.61 percent was soluble in water. Therefore, water-soluble phosphorus formed only a very small percentage of the total phosphorus of the skeleton and the entire body, but made up from one-half to three-fourths of the total phosphorus in the other parts.

Water-Soluble Inorganic Phosphorus.—The values for the water-soluble inorganic phosphorus in percent of the fresh substance ranged from 0.010 percent in the composite of the jowl, leaf, and intestinal fats to 0.099 percent in the boneless meat of the ham cut. The values for the offal, side cut, entire carcass, and entire body were about the same, varying only from 0.067 percent in the boneless meat of the side cut to 0.078 percent in the offal. The skeleton (bone and marrow) contained only 0.029 percent[b].

On the basis of the dry and fat-free substance, the order of the parts according to increasing content of water-soluble inorganic phosphorus was as follows: skeleton; blood; composite of jowl, leaf, and intestinal fats; offal; and boneless meat of side, shoulder, and ham cuts.

The amount of water-soluble inorganic phosphorus per 100 pounds live weight varied from 0.31 gram in the composite of the jowl, leaf, and intestinal fats to 31.45 grams in the entire body. The boneless meat of the carcass contained as much as 23.04 grams, and the skeleton, as little as 1.26 grams.

The percentage distribution agreed fairly well with that of the total water-soluble phosphorus. The chief difference was found in the blood in which the value for the water-soluble inorganic phosphorus was 1.56 percent, and that for the total water-soluble phosphorus, 4.91 percent[a].

---

[a]See Fig. 5, page 230.

[b]See Fig. 4, page 229.

The water-soluble inorganic phosphorus in the body and its parts in percent of the total phosphorus in the body and each part varied from 4.80 percent in the skeleton to 66.10 percent in the boneless meat of the ham cut. It formed 10.07 percent of the total phosphorus in the entire body.

Expressed in percent of the total water-soluble phosphorus in the body and each part, the values for the water-soluble inorganic phosphorus show that, with the exception of the blood, from 71 to 92 percent of the total water-soluble phosphorus was inorganic. The water-soluble inorganic phosphorus formed also 86.66 percent of the total water-soluble phosphorus in the entire body.

CHANGES IN TOTAL PHOSPHORUS CONTENT OF PIGS DURING GROWTH

The young pigs of Lot IV were used as a control in order to determine the nature of the chemical changes that occurred in the bodies of the pigs of Lots I, II, and III during the experiment. For this study, the averages of the data for the two pigs of Lot IV have been compared with the averages of the data for the five pigs of Lots I, II, and III. The results are given in Table 12 as Series I and II, respectively.

The age of the pigs of Series I, when slaughtered, was 18 weeks; that of Pigs 1, 5, and 16 of Series II, 42 weeks and 6 days; and that of Pigs 7 and 13 of Series II, 40 weeks.

From the data in Table 12 for the total phosphorus expressed in percent of the fresh substance, it will be noted that in the case of the offal and entire body there was comparatively little difference between the values for the two series. In the case of the skeleton, the percentage for the pigs of Series I was considerably lower than that for the pigs of Series II, while in the case of the jowl, leaf, and intestinal fats, and the boneless meat of the entire carcass, it was considerably higher.

On the basis of the dry and fat-free substance, the average percentage of phosphorus for the pigs of Series I was higher for the offal, the composite of the fats, and the boneless meat of the entire carcass than that for the pigs of Series II, and lower for the skeleton and entire body.

The amount of phosphorus per pig shows, as would be expected, that each of the parts of the pigs of Series II contained more than the corresponding parts of the pigs of Series I. The increase of phosphorus varied greatly in the different samples. It was largest in the skeleton, 420.85 grams, and smallest in the composite of the fats, 1.27 grams. In the entire body the increase was 467.83 grams.

On the basis of 100 pounds live weight, the offal and the boneless meat of the carcasses of Series I contained more phosphorus than the corresponding parts of the pigs of Series II. This difference was due to an increase with the age and maturity of the pigs in the fat of these parts. The skeleton, the composite of the jowl, leaf, and intestinal fats, and the entire carcasses of the pigs of Series I contained smaller amounts of phosphorus than those of Series II.

The data for the distribution of the total phosphorus among the parts of the body in percent of the total phosphorus in the entire body indicate that during growth there was an increase of 0.07 percent in the composite of the jowl, leaf, and intestinal fats, a decrease of 7.09 percent in the offal, a decrease of 12.27 percent in the boneless meat of the entire carcass, and an increase of 19.29 percent in the skeleton.

The percentage increases in the phosphorus content of the various parts during growth were as follows: offal, 61.01 percent; skeleton, 457.70 percent; composite of the jowl, leaf, and intestinal fats, 488.40 percent; boneless meat of entire carcass, 107.00 percent; and entire body, 329.90 percent.

Less than one-fourth, 22.92 percent, of the phosphorus consumed was retained in the body. The remainder, 77.08 percent, was excreted in the urine and feces. About ninety percent of the phosphorus stored was used in the building up of the skeleton (bone and marrow). Only 7.68 percent was utilized in the boneless meat of the entire carcass.

TABLE 12.—TOTAL PHOSPHORUS CONTENT OF PIGS AS AFFECTED BY GROWTH

	Offal[a]	Skeleton	Jowl, leaf, and intestinal fats	Boneless meat of carcass	Entire body
Series I. Average for Lot IV. Pigs 18 Weeks of Age					
In percent of fresh substance	0.185	4.07	0.077	0.273	0.600
In percent of dry and fat-free substance	0.953	9.47	1.302	1.626	2.810
Grams per pig (average weight 51.0 lbs.)	16.08	91.94	0.26	33.56	141.84
Grams per 100 lbs. live weight	30.98	176.66	0.50	64.57	272.92
In percent of total phosphorus in entire body	11.34	64.82	0.18	23.66	100.00
Series II. Average of Lots I, II, and III. Pigs 40 to 43 Weeks of Age					
In percent of fresh substance	0.150	6.03	0.026	0.123	0.690
In percent of dry and fat-free substance	0.652	10.63	0.824	0.927	3.943
Grams per pig (average weight 195.3 lbs.)	25.89	512.79	1.53	69.46	609.67
Grams per 100 lbs. live weight	13.26	262.66	0.78	35.58	312.27
Grams increase	9.81	420.85	1.27	35.90	467.83
Percentage increase	61.01	457.70	488.40	107.00	329.90
Phosphorus stored in percent of total phosphorus consumed	0.49	20.61	0.06	1.76	22.92
In percent of total phosphorus in entire body	4.25	84.11	0.25	11.39	100.00

[a]Includes blood.

SUMMARY

1. *Plan of Experiment.*—Of fourteen carefully selected Berkshire pigs weighing on an average 51 pounds, two were slaughtered and analyzed at the beginning of the experiment to be used as a control in studying the influenec of the feed on growth. The remaining twelve were then divided into three lots of four pigs each in such a way that the lots were as nearly alike as possible in regard to age, ancestry, weight, and condition. During the experiment, which lasted 174 days, Lot 1 was fed a low-protein ration (0.32 pound of digestible protein per day per 100 pounds live weight); Lot II, a medium-protein ration (0.70 pound of digestible protein per day per 100 pounds live weight); and Lot III, a high-protein ration (0.94 pound of digestible protein per day per 100 pounds live weight). Each ration consisted of ground corn, blood meal, and calcium phosphate. All of the pigs received the same amounts of corn protein per 100 pounds live weight. The blood-meal protein made up 50 percent of the total protein received by the pigs of Lot I, 80 percent of that received by Lot II, and 86 percent of that received by Lot III. Lot I received 3.79 therms of metabolizable energy per 100 pounds live weight per day; Lot II, 4.28 therms; and Lot III, 4.49 therms. The calcium phosphate was so fed that the rations of Lots I, II, and III contained, respectively, 11.09, 9.69, and 8.73 grams of phosphorus per 100 pounds live weight per day. The pigs of the three lots were kept and fed under exactly the same conditions thruout the experiment. Each pig was fed separately. At the end of the experiment the bodies and parts of one pig of Lot I and two pigs from each of Lots II and III were analyzed for total phosphorus, water-soluble phosphorus, and water-soluble inorganic phosphorus.

INFLUENCE OF QUANTITY OF PROTEIN CONSUMED

2. *Total Phosphorus in the Lots.*—The percentages of total phosphorus in the bodies and the parts of the bodies of the low-, medium-, and high-protein lots, respectively, were as follows: composite sample of jowl, leaf, and intestinal fats, 0.016, 0.027, and 0.029; blood, 0.113, 0.115, and 0.128; boneless meat of side cut, 0.115, 0.106, and 0.102; boneless meat of carcass, 0.129, 0.123, and 0.120; boneless meat of shoulder cut, 0.132, 0.131, and 0.130; offal (including blood), 0.148, 0.152, and 0.149; boneless meat of ham cut, 0.154, 0.153, and 0.145; entire body, 0.728, 0.681, and 0.679; and skeleton, 5.69, 6.19, and 6.03.

3. *Total Water-Soluble Phosphorus in the Lots.*—The percentages of water-soluble phosphorus in the bodies and the parts of the bodies of the low-, medium-, and high-protein lots, respectively, were as follows: composite sample of jowl, leaf, and intestinal fats, 0.011,

0.015; and 0.015; skeleton, 0.035, 0.034, and 0.032; boneless meat of side cut, 0.075, 0.070, and 0.075; entire body, 0.082, 0.079, and 0.080; boneless meat of carcass, 0.085, 0.081, and 0.083; offal (including blood), 0.098, 0.098, and 0.102 boneless meat of shoulder cut, 0.105, 0.094, and 0.096; blood, 0.113, 0.115, and 0.128; and boneless meat of ham cut, 0.114, 0.111, and 0.102.

4. *Water-Soluble Inorganic Phosphorus in the Lots.*—The percentages of water-soluble inorganic phosphorus in the bodies and the parts of the bodies of the low-, medium-, and high-protein lots, respectively, were as follows:—composite sample of jowl, leaf, and intestinal fats, 0.007, 0.011, and 0.011; skeleton, 0.032, 0.028, and 0.028; entire body, 0.071, 0.071, and 0.067; boneless meat of carcass, 0.076, 0.075, and 0.071; boneless meat of side cut, 0.077, 0.066, and 0.063; offal (including blood), 0.077, 0.077, and 0.079; boneless meat of shoulder cut, 0.089, 0.091, and 0.080; and boneless meat of ham cut, 0.096, 0.105, and 0.093.

5. *Phosphorus Stored in the Body.*—When the phosphorus stored by the pigs of the low- and high-protein lots from the beginning to the end of the experiment was calculated to the basis of the amounts of phosphorus consumed per 100 pounds live weight by the pigs of the medium-protein lot, it was found that the percentages stored by Lots I, II, and III, respectively, were 23.81, 23.85, and 23.10 percent.

AVERAGE PHOSPHORUS CONTENT OF GROWING PIGS 40 TO 43 WEEKS OLD

6. *Phosphorus Content of Entire Body.*—The averages of the percentages for the different forms of phosphorus in the bodies of the five pigs were: total phosphorus, 0.690; total water-soluble phosphorus, 0.079; and water-soluble inorganic phosphorus, 0.069. On the basis of the dry and fat-free substance, the corresponding values were 3.943, 0.425, and 0.369 percent. Of the total phosphorus, 11.61 percent was soluble in water. The water-soluble inorganic phosphorus made up 86.66 percent of the total water-soluble phosphorus. The average amount of total phosphorus in the bodies of the pigs per 100 pounds live weight was 312.29 grams; the average amount of total water-soluble phosphorus, 36.28 grams; and the average amount of water-soluble inorganic phosphorus, 31.45 grams.

7. *Distribution of Phosphorus Among the Parts of the Body.*—The data for the distribution of the total, water-soluble, and water-soluble inorganic phosphorus among the parts of the body showed that in the skeleton (bone and marrow) the percentages of these three forms of phosphorus were, respectively, 84.11, 4.00, and 4.01; in the boneless meat of the carcass, 11.39, 70.06, and 73.30; in the offal (in-

cluding blood), 4.25, 24.73, and 21.70; in the blood, 0.51, 4.91, and 1.56; and in the composite of the jowl, leaf, and intestinal fats, 0.25, 1.21, and 0.99.

8. *Phosphorus Content of Boneless Meat of Carcass.*—The averages of the percentages of phosphorus in the boneless meat of the carcasses of the five pigs were: total phosphorus, 0.123; total water-soluble phosphorus, 0.083; and water-soluble inorganic phosphorus, 0.074. On the basis of the dry and fat-free substance, the corresponding values were, 0.927, 0.622, and 0.554 percent, respectively. Of the total phosphorus, 71.44 percent was soluble in water. Of the total water-soluble phosphorus 90.67 percent was inorganic. On the basis of 100 pounds live weight, the average amounts of phosphorus in the boneless meat of the entire carcass were: total phosphorus, 35.58 grams; total water-soluble phosphorus, 25.42 grams; and water-soluble inorganic phosphorus, 23.04 grams.

9. *Phosphorus Content of Skeleton (Bone and Marrow).*—The averages of the percentages of the five pigs for the total, water-soluble, and water-soluble inorganic phosphorus, respectively, in the skeletons, were: 6.03, 0.033, and 0.029. On the basis of the dry and fat-free substance, the corresponding values were 10.63, 0.059, and 0.051 percent. Only 5.52 percent of the total phosphorus was soluble in water. Of the soluble phosphorus, 86.93 percent was inorganic. On the basis of 100 pounds live weight, the skeleton contained 262.66 grams of total phosphorus, 1.45 grams of water-soluble phosphorus, and 1.26 grams of water-soluble inorganic phosphorus.

CHANGES IN TOTAL PHOSPHORUS CONTENT OF PIGS DURING GROWTH

10. *Percentage Phosphorus Content.*—The percentages of total phosphorus in the bodies and the parts of the bodies of the pigs 18 weeks of age, and of those 40 to 43 weeks of age were, respectively, as follows: composite sample of jowl, leaf, and intestinal fats, 0.077 and 0.026 percent; offal (including blood), 0.185 and 0.150 percent; boneless meat of carcass, 0.273 and 0.123 percent; entire body, 0.600 and 0.690 percent; and skeleton, 4.07 and 6.03 percent.

11. *Phosphorus per 100 Pounds Live Weight.*—The amounts of total phosphorus in the bodies and the parts of the bodies of the pigs 18 weeks of age, and of those 40 to 43 weeks of age per 100 pounds live weight, were, respectively, as follows: composite sample of the jowl, leaf, and intestinal fats, 0.50 and 0.78 gram; offal (including blood), 30.98 and 13.26 grams; boneless meat of carcass, 64.57 and 35.58 grams; skeleton, 176.66 and 262.66 grams; and entire body, 272.92 and 312.27 grams.

12. *Increase During Growth.*—The average amounts of phosphorus added to the body and the parts of the body during the 174 days of the experiment were as follows: to the composite sample of the jowl, leaf, and intestinal fats, 1.27 grams; to the offal (including blood), 9.81 grams; to the boneless meat of the carcass, 35.90 grams; to the skeleton, 420.85 grams; and to the entire body, 467.83 grams.

13. *Percentage Increase During Growth.*—The percentage increase in the total phosphorus in the body and the parts during the experiment was as follows: in the offal (including blood), 61.01; in the boneless meat of the carcass, 107.00; in the entire body, 329.90; in the skeleton, 457.70; and in the composite of the jowl, leaf, and intestinal fats, 488.40.

14. *Phosphorus Stored in the Body.*—Of the phosphorus consumed during the experiment, 22.92 percent was stored in the body. The remainder, 77.08 percent, was excreted in the urine and feces. The amounts of phosphorus stored in the parts of the body in percent of the phosphorus consumed were as follows: in the composite sample of the jowl, leaf, and intestinal fats, 0.06 percent; in the offal, (including blood), 0.49 percent; in the boneless meat of the carcass, 1.76 percent; and in the skeleton (bone and marrow), 20.61 percent.

15. *Distribution of Total Phosphorus.*—The percentage distribution of the total phosphorus in the bodies of the young and older pigs, respectively, was: in the composite sample of the jowl, leaf, and intestinal fats, 0.18 and 0.25; in the offal (including blood), 11.34 and 4.25; in the boneless meat of the carcass, 23.66 and 11.39; and in the skeleton, 64.82 and 84.11.

CONCLUSIONS

From the experimental data given in this bulletin, the following conclusions may be drawn:

1. Variations in the amounts of digestible protein consumed, from 0.32 pound to 0.94 pound per 100 pounds live weight per day, do not influence significantly the percentages or distribution of the total, the water-soluble, or the water-soluble inorganic phosphorus in the bodies or the parts of the bodies of growing pigs.

2. The total phosphorus in the bodies of pigs 40 to 43 weeks of age is distributed among the parts as follows: about four-fifths in the skeleton, one-ninth in the boneless meat of the carcass; one-twentieth in the offal (including blood), and one-four-hundredth in the composite of the jowl, leaf, and intestinal fats. The water-soluble phosphorus makes up about seven-tenths of the total phosphorus in the boneless meat of the carcass, two-thirds of that in the offal, one-half of that in the composite of the jowl, leaf, and intestinal fats, one-

ninth of that in the entire body, and one-twentieth of that in the skeleton. About nine-tenths of the water-soluble phosphorus in the boneless meat of the carcass, seven-tenths of that in the entire body, seven-eighths of that in the skeleton, and three-fourths of that in the offal is in the inorganic form.

3. During the period of growth from the time pigs are 18 weeks old (51 pounds live weight), until they are 40 to 43 weeks old (195 pounds live weight), the percentage of total phosphorus in the skeleton is increased about one-half, and that in the entire body is increased about three-twentieths. In the boneless meat of the carcass and in the composite of the jowl, leaf, and intestinal fats, the percentage of total phosphorus is decreased about one-half. The percentage increase of the phosphorus is 458 percent in the skeleton, 330 percent in the entire body, and 107 percent in the boneless meat. The phosphorus stored in the body during growth is equal to 23 percent of the total phosphorus consumed during the same period of time.

The authors wish to express to Professor H. S. Grindley, Chief in Animal Nutrition, their appreciation of his valuable advice and suggestions given in connection with this research. They are indebted for assistance also to Dr. W. E. Joseph, Associate in Animal Husbandry, and Professor William Dietrich, formerly Assistant Chief in Swine Husbandry. To Miss Leonora Perry they wish to express their appreciation of her very efficient editorial criticism.

BIBLIOGRAPHY

1. Williams and Emmett, *Ill. Agr. Exp. Sta. Bul. 169 (1914).*

2. Jordan, Hart, and Patten, *N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 1 (1906).* Mendel and Underhill, *Amer. Jour. Physiol., 17, 75 (1906).* LeClerc and Cook, *Jour. Biol. Chem., 2, 203 (1906).* Forbes, *Ohio Agr. Exp. Sta. Buls. 213 (1909)* and *271 (1914).* Hart, McCollum, and Fuller, *Wis. Agr. Exp. Sta. Res. Bul. 1 (1909).* Hart, McCollum, and Humphrey, *Amer. Jour. Physiol., 24, 86 (1909).* Cook, *U. S. Bur. Chem. Bul. 123 (1909).* Burnett, *Neb. Agr. Exp. Sta. Bul. 107 (1908).* Hart, Steenbock, and Fuller, *Wis. Agr. Exp. Sta. Bul. 30 (1914).* Good, *Ky. Agr. Exp. Sta. Bul. 175 (1914).*

3. Herter, *Jour. Exp. Med., 3, 293 (1898).* Sherman, *U. S. Office Exp. Stas. Bul. 227 (1910).* LeClerc and Cook, *Jour. Biol. Chem., 2, 203 (1906).* Masslow, *Biochem. Ztschr., 55, 45 (1913).*

4. Kohler, *Landw. Vers. Stat., 65, 349 (1907).* LeClerc and Cook, *Jour. Biol. Chem., 2, 203 (1906).* Hart, McCollum, and Fuller, *Wis. Agr. Exp. Sta. Res. Bul. 1 (1909).* Cook, *U. S. Bur. Chem. Bul. 123 (1909).* McCollum, *Wis. Agr. Exp. Sta. Res. Bul. 8 (1910).*

Forbes, *Ohio Agr. Exp. Sta. Bul. 222 (1910).* Dox, *Jour. Biol. Chem., 10, 77 (1911).* Gregersen, *Ztschr. physiol. Chem., 71, 49 (1911).* Masslow, *Biochem. Ztschr., 56, 174 (1913).* Forbes, *Proceedings Soc. Prom. Agr. Sci. (1913).*

5. Emmett and Grindley, with the cooperation of Joseph and Williams, *Ill. Agr. Exp. Sta. Bul. 168 (1914).*

6. Hart and Andrews, *Amer. Chem. Jour., 30, 470 (1903).* Emmett and Grindley, *Jour. Amer. Chem. Soc., 28, 25 (1905).*

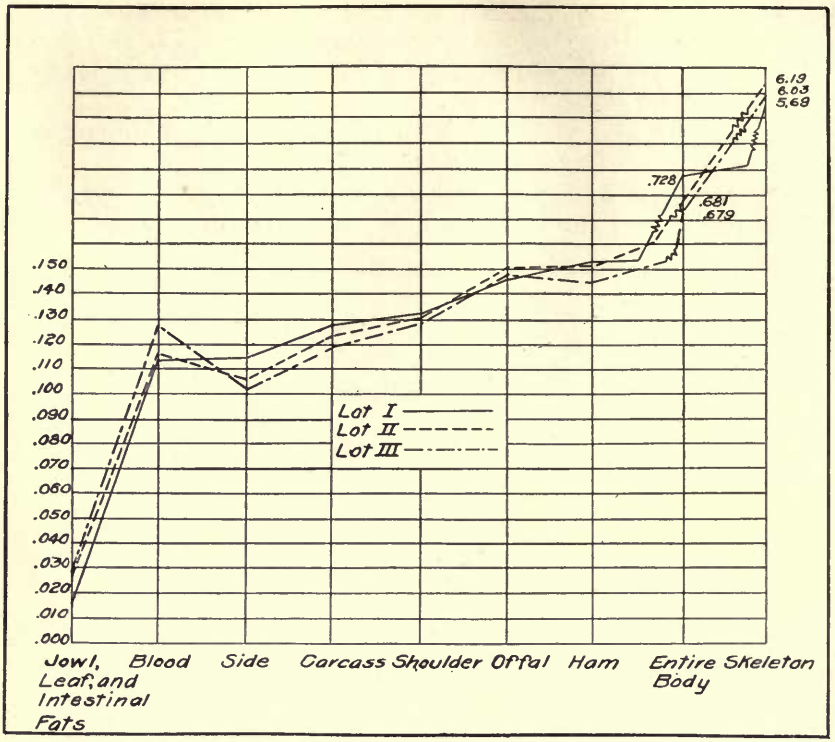


FIG. 1.—PERCENTAGES OF TOTAL PHOSPHORUS IN THE BODIES AND THEIR PARTS

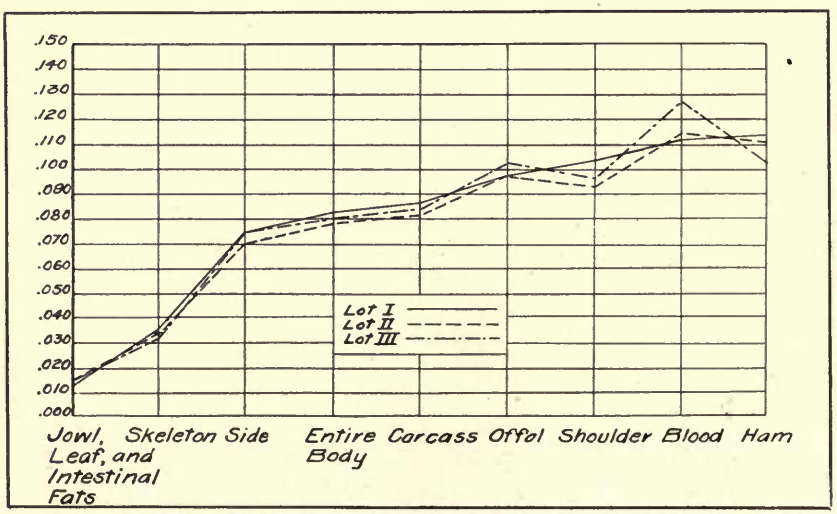


FIG 2.—PERCENTAGES OF WATER-SOLUBLE PHOSPHORUS IN THE BODIES AND THEIR PARTS

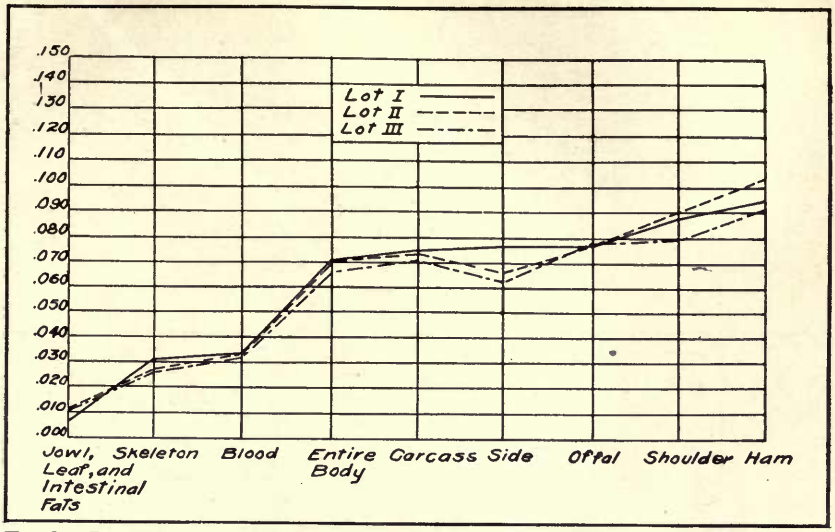


FIG 3.—PERCENTAGES OF WATER-SOLUBLE INORGANIC PHOSPHORUS IN THE BODIES AND THEIR PARTS

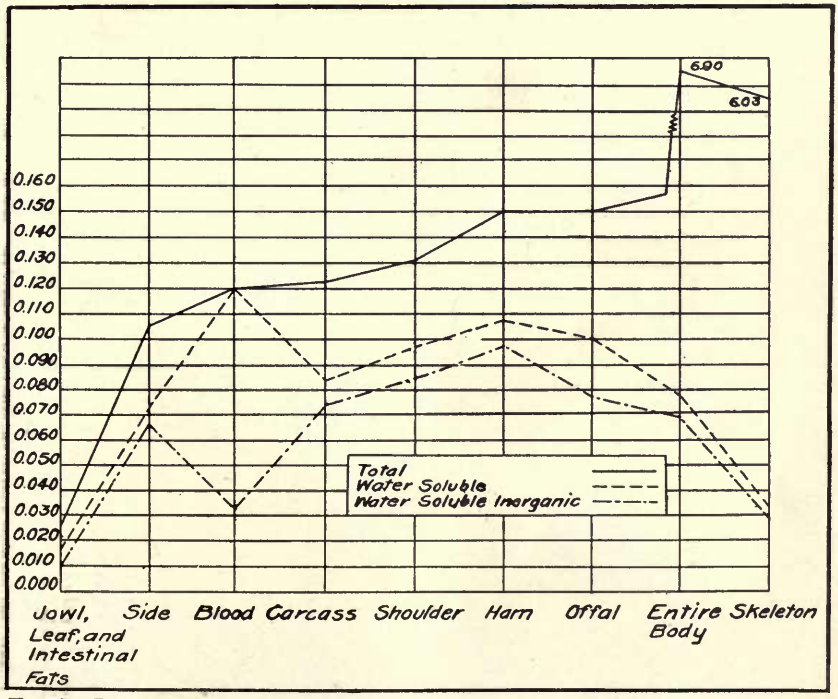


FIG 4.—PERCENTAGES OF FORMS OF PHOSPHORUS IN THE BODIES AND PARTS OF THE PIGS 40 TO 43 WEEKS OLD

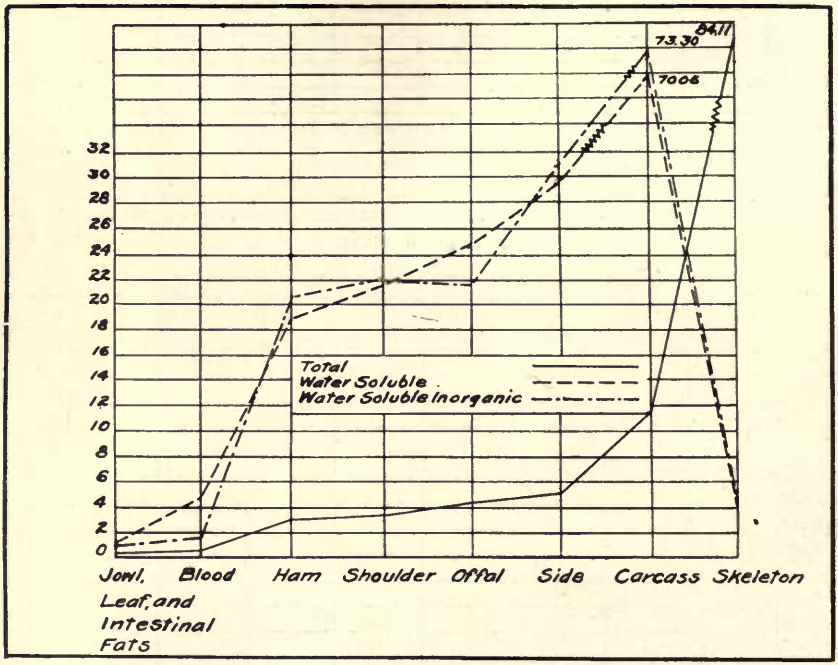


FIG 5.—DISTRIBUTION OF FORMS OF PHOSPHORUS AMONG THE PARTS OF THE PIGS 40 TO 43 WEEKS OLD